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SITE Technology Capsule

Geosafe Corporation In Situ Vitrification Technology

Abstract

The Geosafe In Situ Vitrification (ISV) Technology Is designed to treat soils, sludges, sediments, and mine tallings contaminated with organic, inorganic, and radioactive compounds. The organic compounds are pyrolyzed and reduced to **simple gases** which are collected under a treatment hood and processed prior to their emission to the atmosphere. Inorganic and radioactive contaminants are incorporated into the molten soil which solidifies to a vitrified mass similar to volcanic obsidian.

This mobile technology was evaluated under the SITE Program on approximately 330 yd^3 of contaminated soil at the Parsons site. Demonstration results indicate that the cleanup levels specified by EPA Region V were met and that the vitrified soil did not exhibit leachability characteristics in excess of regulatory guidelines. Process emissions were also within regulatory limits.

The Geosafe ISV Technology was evaluated based on seven criteria used for decision-making in the Superfund Feasibility Study (FS) process. Results of the evaluation are summarized In Table 1.

introduction

This Capsule provides information on the Geosafe ISV Technology, a process designed to treat contaminated media by using an electrical current to heat and vitrify the subject material. The Geosafe ISV Technology was investigated under the Environmental Protection Agency (EPA) Super-fund Innovative Technology Evaluation (SITE) Program during March and April 1994 at the former site of Parsons Chemical Works, Inc. (Parsons). The Parsons site Is a Super-fund site located in Grand Ledge, MI and currently undergoing a removal action under the supervision of the EPA Reglon V. Soils at the Parsons site were previously contaminated by normal facility operatlons including the mixing, manufacturing, and packaging of agricultural chemicals. The technology was evaluated on these soils which were contaminated with pesticides (primarily chlordane, dieldrin, and 4,4'-DDT),metals (especially mercury), and low levels of dloxins/furans. A total of approximately 3,000 yd^3 of contaminated soil was treated In nine pre-staged treatment settings. The Demonstratton Test evaluated the system performance on one of these settings.

Information in this Capsule emphasizes specific site characteristics and results of the SITE Demonstration at the Parsons site. This Capsule presents the following information:

- Technology Description
- Technology Applicability
- Technology Limitations
- Site Requirements
- Process Residuals
- Performance Data
- Economic Analysis
- Technology Status
- SITE Program Description
- Sources of Further Informatlon

Technology Description

The ISV Technology demonstrated by Geosafe Corporation (Richland, WA) operates by means of four graphite electrodes, arranged in a square and inserted a short distance into the soil to be treated. A schematic of the Geosafe process is presented in Figure 1.

ISV uses electrical current to heat (melt) and vitrify the treatment material in place. A pattern of electrically conductive graphite containing glass frit Is placed on the soil In paths between the electrodes. When power is fed to the electrodes, the graphite and glass frit con-

SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

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Table 1. Criteria Evaluation for the Geosafe In Situ Vitrification Technology

Criteria						
Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-Term Effectiveness	Short- Term Effectiveness	Reduction of Toxicity, Mobility, or Volume through Treatment	Implementability	Cost
Provides both short- and long-term protection by destroying organic contaminants and immobilizing inorganic material. Remediation can be performed in situ, thereby reducing the need for excavation. Requires off-gas treatment system to control airborne emissions. System can be specifically designed to handle emissions generated by the contaminants in the media being treated. Technology can simultaneously treat a mixture of waste types (e.g., organic and inorganic wastes).	Requires compliance with RCRA treatment, storage, and land disposal regulations (for a hazardous waste). Successfully treated solid waste may be delisted or handled as nonhazardous waste. Operation of on-site treat ment unit may require compliance with location-specific ARARs. Emission controls may be **needed** to ensure compliance with air quality standards depending upon local ARARs and test soil components. Scrubber water will likely require secondary treatment before discharge to POTW or surface bodies. Disposal requires compliance with Clean Water Act regulations.	Effectively destroys organic contamination and immobilizes inorganic material Reduces the likelihood of contaminants leaching from treated soil. ISV glass is thought to have a stability similar to volcanic obsidian. The vitrified product is conservatively estimated to remain physically and chemically stable for approximately 7,000,000 years. May allow re-use of property after remediation.	Effectively destroys organic contamination and immobilizes inorganic material. Vitrification of a single 15-ft deep treatment **setting** may be accomplished in approximately ten days. Treatment times will vary with actual treatment depth and site-specific conditions. Presents potential short-term exposure risks to workers operating process equipment. Temperature and **electric** hazards exist. Some short-term risks associated with air emissions are dependent upon test material composition and off-gas treatment system design. Staging, if required. involves excavation and construction of treatment areas. A potential for fugitive emissions and exposure exists during excavation and construction.	Significantly reduces toxicity and mobility of soil contaminants through treatment. Volume reductions of 20 to 50% are typical after treatment. Some inorganic contaminants, especially volatile metals, may escape the vitrification process and require subsequent treatment by the off-gass treatment system. Some treatment residues (e.g., filters, personal protective equipment) may themselves be treated during subsequent vitrification settings. Residues from the final setting, including expended or contaminated processing equipment may require special disposal requirements. Volume of scrubber water generated is highly dependent upon soil moisture content, ambient air humidity, and soil particulate levels in the off-gas.	A suitable source of electric power is required to utilize this technology. Equipment is transportable and can be brought to a site using conventional shipping methods. Weight restrictions on tractors/trailers may vary from state to state. Necessary support equipment includes earthmoving equipment for staging treatment areas (if required) and covering treated areas with clean soil. A crane is required for off-gas hoodplacement and movement. The staging of treatment areas is recommended for areas where the contamination is limited to shallow depths (less than eight feet). The soil oxide composition must provide sufficient electrical conductivity in the molten state and adequate quantites of glass formers to produce a vitrified product. Oxides can be added to soil to corrected for deficiencies. Groundwater should be diverted away from treatment area to improve economic viability.	The estimated cost for treatment when the soil is staged into nine 15-ft deep cells is approximately **$\$780/\text{yd}^3$** ($430/ton). This cost is based on data gathered from the Parsons site. Costs are highly site-specific and will vary with on-site **conditions.** Treatment is most economical when treating large sites to maximum depths. Electric power is a major element of when associated with ISV processing. Other important factors (in order of significance) include labor costs; startup and fixed costs; equipment costs; and facility modifications and maintenance costs. Moisture content of the media being treated directly influences the cost of treatment since electric energy must be used to vaporize water before soil melting occurs. Sites that require staging and extensive site preparation will have higher overall costs.

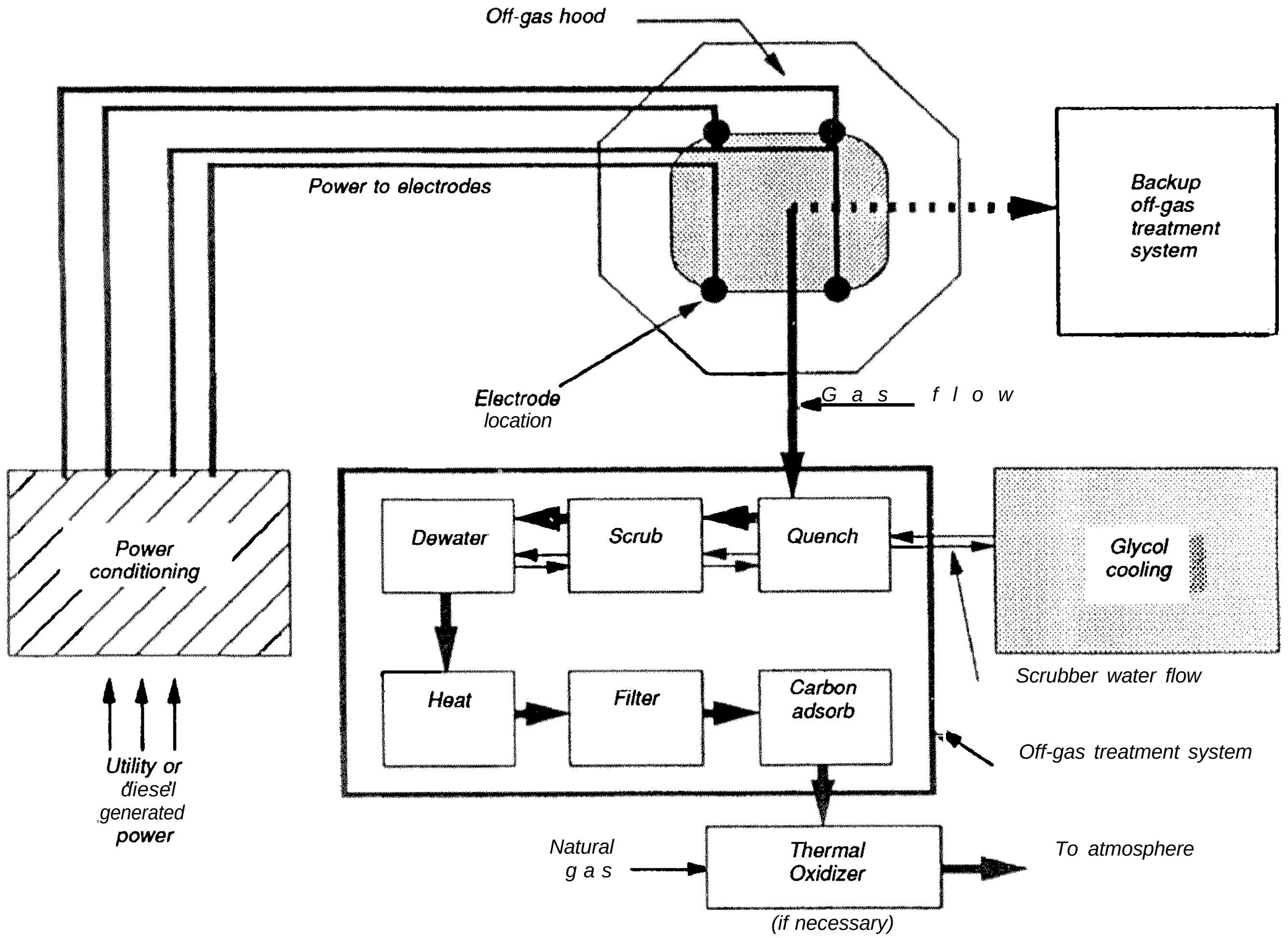


Figure 1. Geosafe in situ vitrification process

ducts the current through the soil, heating the surrounding area and melting directly adjacent soil.

Molten soils are electrically conductive and can continue to carry the current which heats and melts soil downward and outward. The **electrodes are allowed to progress down into the soil** as it becomes molten, continuing the melting process to the desired treatment depth. One setting of four electrodes is referred to as a "melt." Performance of each melt occurs at an average rate of approximately three to four tons/hr.

When all of the soil within a treatment setting becomes molten, the power to the electrodes is discontinued and the molten mass begins to cool. The electrodes are cut near the surface and allowed to settle into the molten soil to become part of the melt. Inorganic contaminants in the soil are generally incorporated into the molten soil which solidifies Into a monolithic vitrified mass similar in characteristics to volcanic obsidian. The vitrified soil is dense and hard, and significantly reduces the possibility of leaching from the mass over the long term.

The organic contaminants in the soil undergoing treatment are pyrolyzed (heated to decomposition temperature without oxygen) and are generally reduced to simple gases. The gases move to the surface through the dry zone immediately adjacent to the melt, and through the melt itself. Gases at the surface are collected under a stainless steel hood placed over the treatment area and then treated in an off-gas treatment system. The off-gas treatment system comprises a quencher, a scrubber, a demister, high efficiency particulate air (HEPA) filters, and activated carbon adsorption to process the offgas be fore releasing the cleaned gas through a stack. A thermal oxidizer can be used following the off-gas treatment system to polish the offgas before release to the atmosphere. A thermal oxidizer was utilized during the SITE Demonstration at the Parsons site.

Technology Applicability

The Geosafe ISV Technology is a stand-alone process that can be used to treat a wide variety of media including soils, sludges, sediments, and mine tailings. It is a mobile system with process equipment permanently mounted on three trailers. The hood and remaining equipment are transported on two additional trailers.

The soil type treated during the Demonstration was a clay-like soil with some sand and gravel present. Contamlnants suitable for remediation by this technology may be organic or inorganic. The technology has also been successfully demonstrated on radioactive and mixed (hazardous and radioactive) wastes by Battelle Memorial Institute for the U.S. Department of Energy, but supporting data for this claim was not gathered as part of the Demonstration Test. Testing to date does not indicate an upper limit of contamination restricting successful remediation if the composition of the material is suitable for treatment (see Technology Limitations). The technology is also being developed for buried waste, underground tank, and barrier wall applications.

The technology can remediate contaminated materials in situ. Alternatively, contaminated materials may be excavated, consolidated, and staged in prepared treatment settings when the contamination zones are shallow (less than eight ft) or scattered. Other processing configurations are under development for unique applications.

Technology Limitations

The technology has the capability of treating large areas in multiple treatment settings. The size of each treatment setting is dependent on the electrode spacing appropriate for remediation. At the Parsons site, each treatment setting covered a 27-ft by 27-ft ground surface area. Adjacent settings can be melted until the entire contaminated area is treated. Melt settings are configured such that each area melts and fuses into the previous setting, leaving one large vitrified block after treatment. This overlap ensures treatment of the material between settings.

The maximum acceptable treatment depth with the current equipment is 20 ft below land surface (BLS): however, full-scale tests at Geosafe's testing facilities in Richland, WA have demonstrated that the technology can successfully reach a depth of approximately 22 ft BLS. Treatment at the Parsons site typically reached depths of 15to 19 ft BLS.

The presence of large amounts of water in the treatment media may hinder the rate of successful application of the Geosafe technology since electrical energy is initially used to vaporize this water instead of melting the contaminated soil. The resulting water vapors must also be handled by the off-gas treatment system. Treatment times are thus prolonged and costs increased when excess water is present.

The overall oxide composition of the test soil determines properties such as fusion and melting temperatures, and melt viscosity. Soil to be treated must contain sufficient quantities of conductive cations (K, Li and Na) to carry the current within the molten mass. Additionally, the soil should contain acceptable amounts of glass formers (Al and Si). Most soils worldwide have an acceptable composition for ISV treatment without composition modification. Geosafe determines the oxides present in the soil prior to treatment. A computer-based model is then used to determine the applicability of the site for vitrification. The model can also identify oxide composition levels that require modification before treatment.

The type of contamination present on-site affects the off-gas treatment system more dramatically than it affects the rest of the ISV system. For this reason, the off-gas treatment system is modular in configuration, allowing treatment of the off-gases to be site-specific. The extent of modularity is expected to increase with future units.

Heat removal limitations of the current equipment dictate that the organic content of the treatment media be less than 7 to 10% by weight. To minimize pooling of treated metals at the bottom of a melt, which may result in electrical short-circuiting, metals content must be less than 15% by weight. The volume of inorganic debris is limited to 20% or less.

Previous experience has indicated that safe, effective treatment cannot be assured when pockets of vapor or buried drums exist beneath the soil surface. The gases released may cause bubbling and splattering of molten material, resulting in a potential safety hazard. For this reason, extensive site characterization is recommended prior to treatment if buried drums are suspected. Combustible materials generally do not present processing difficulties since they decompose relatively slowly as the melt front approaches. Full-scale demonstrations have been successfully conducted on sites containing significant quantities of combustibles such as wooden timbers. automobile tires, personal protective equipment, and plastic sheeting.

Site Requirements

The site requirements for the Geosafe ISV technology are a function of the size of the equipment used. The site requirements are also determined, in part, by whether the soil is excavated and staged prior to treatment. Adequate area is required to accommodate staging, if employed, and to support the off-gas treatment system and the power conditioning system which feeds the electrodes. Space for maneuvering a crane is also necessary to allow placement and removal of the off-gas containment hood and to assist in the placement of the electrodes.

At the Parsons site, the original soil contamination was relatively shallow, five ft or less, and located in three main areas. To increase the economic viability of treatment at this site, the contaminated soil was excavated and consolidated into a series of nine treatment cells. The cell walls were built using concrete, cobble, and particle board as shown in Figures 2 and 3. The cells were constructed by trenching an area of the site, installing particle board and concrete forms, and pouring concrete into the forms to create the nine cell settings. A one-ft layer of cobble was placed in the bottom of each cell, and approximately two ft of cobble was used to surround the exterior of the cell forms. The use of cobble at the sides was intended as a means to retard melting out into adjacent clean soil. The bottom cobble was used to provide a drainage pathway for water that was known to be present on-site; the resultant flow of water was directed to a drainage trench. After construction, the cells were filled with contaminated soil from the site, and topped with a layer of clean soil.

During the treatment of the first few cells, problems with the cell design were observed. The intense heat that was melting the soil was also thermally decomposing the particle board forms. Analysis of water samples collected from the diversion system surrounding the cells identified volatiles (benzene), phenolics, and epoxies that were

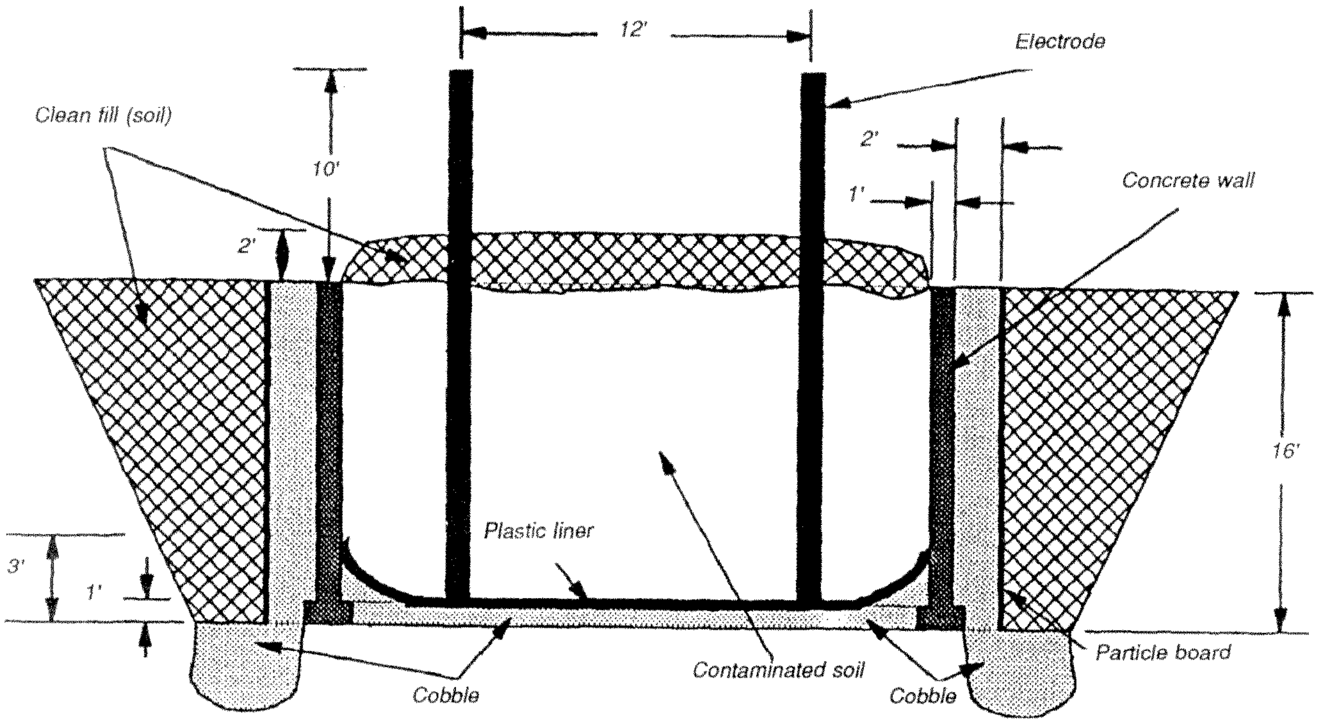
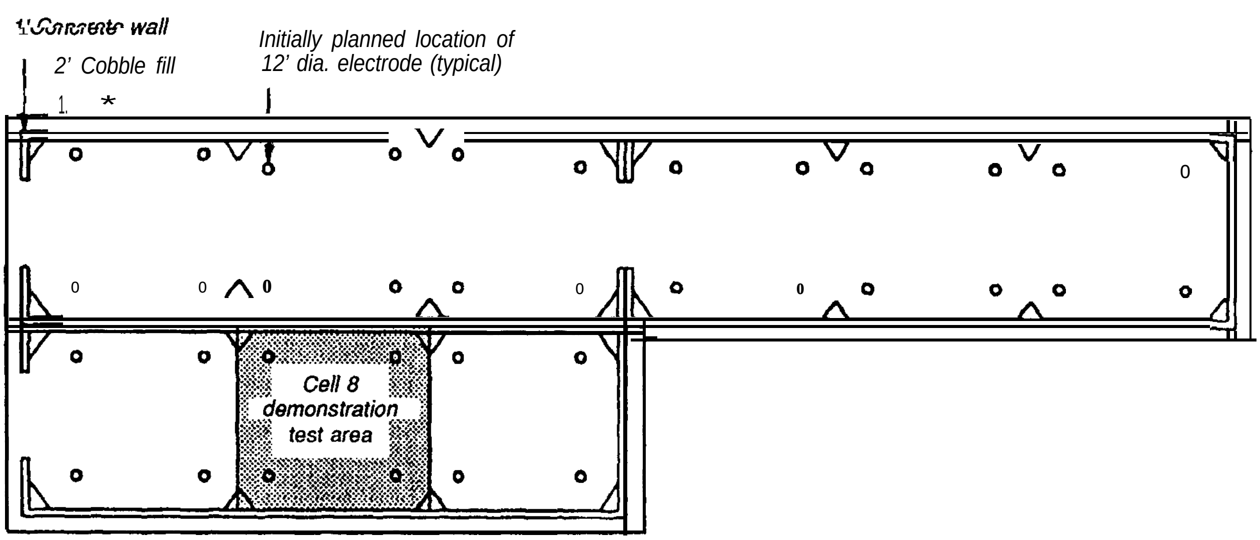


Figure 2. Side view of typical treatment cell.



. *Clean fill surrounds cobble.*

Figure 3. Plan view of treatment cells.

released by this decomposition, The cobble outside of the cells created porous paths In the vicinity of treatment, thereby increasIng the likelihood of vapors escaping the area outside the hood and causing irregular melt shapes.

Geosafe responded by excavating the area outslde of the remaining treatment cells and removing the particle board forms. A refractory ceramic material wlth insulating and reflective properties was placed adjacent to the exterior of the concrete cell walls. This helped to control the melt shape, limit fugitive vapor emissions, and restrict the melt energy insIde the cell boundaries. Based upon the experience Geosafe gained at the Parsons site. the design and construction of staged treatment cells will be modified for future projects, it should be noted that the use of cobble in treatment cell construction was unique to the Parsons site where the configuration and flow of the on-site groundwater dictated Its application.

Utility requirements for thls technology include electricity, natural gas (If a thermal oxidizer Is used), and water. As expected, electricity is a major consideration when implementing ISV. Total power to the electrodes during treatment is approximately three MW; the voltage applied to each of the two phases durlng steady state processing averages around 600 volts while the current for each phase averages approximately 2,500 amps. During treatment of the Demonstration Test cell (Cell 8). energy to the electrodes totalled 613 MW/h. Energy demands for other cells at the Parsons site differed-primarily because of variations in the soil moisture content.

Process Residuals

The primary residual generated by the Geosafe ISV technology is the vltrlfied soil product. Thls material is generally left Intact and In place at the conclusion of treatment. The treated volume may take one to two years to cool completely.

A number of secondary process waste streams are generated by the Geosafe technology. These include alr emissions, scrubber liquor, decontamination liquid, carbon filters, scrub solution bag filters, HEPA filters, used hood panels, and personal protective equipment (PPE). Gaseous emissions which meet regulatory requirements are discharged directly to the atmosphere following treatment. The amount of scrubber liquor and filter waste generated depends on the nature of the treatment media. Factors such as high off-gas particulate loading and high soil moisture content may result In large quantities of these materials. The number of used hood panels requiring disposal depends on the type and extent of contamination at the site, the corrosiveness of the off-gases generated during treatment (as well as the corrosion-resistance of the hood panels), and the duration of treatment.

Some process residuals (e.g., used scrub solution bag filters, HEPA filters, and PPE) can be disposed in subsequent melt settings to reduce the volume of these materials requiring ultimate disposal off-site. Scrubber water generated during treatment may require special handling depending upon the type and level of contaminants being treated.

Performance Data

The Geosafe ISV technology was evaluated to determine its effectiveness in treating soil contaminated wlth pesticides and metals. Cell 8 was selected for the Demonstration Test since it exhibited the highest levels of contamination whereby demonstration objectives could be evaluated. The critical objective for this project was to determine if final soil cleanup levels set by the EPA Region V could be achieved. These specified cleanup levels included 1,000 µg/kg for chlordane. 4,000 µg/kg for 4,4'-DDT, 80 µg/kg for dleldrln, and 12,000 µg/kg for mercury. Non-crlttcal objectives for this project were:

- to evaluate the leachability characteristics of chlordane, 4,4'-DDT, dieldrin, and mercury in the pretreatment soil using the toxicity characteristic leachability procedure (TCLP)and determine whether the leachability characterlsttcs of these compounds in the vitrified residue meet the regulatory limits specified In 40 CFR 261.24. (Note: only chlordane and mercury are listed.);
- to determlne the approximate levels of dioxins/furans, pesticides (specifically chlordane, 4,4'-DDT, and dieldrln), mercury, and moisture in the pretreatment soil;
- to characterlze the liquid residues (scrubber water) of the process with respect to pesticide and mercury concentrations:
- to evaluate emissions from the process;
- to identify the operational parameters of the technology:
- to develop operating costs and assess the reliability of the equlpment: and
- to examlne potentlal impediments to the use of the technology including technical, institutional. operational, and safety impediments.

Approximately 3,000 yd^3 (5,400 tons) of contaminated soil was excavated and staged into nine treatment cells. Prior to treatment, three primary soil cores were obtained from Cell 8 to characterize the concentrations of pesticides, dioxins/furans, and metals. Samples were also collected to determine the leachability characteristics of pesticides and mercury before treatment. In addition, samples were taken for the analysis of grain size, moisture, density, and permeability. Prior to treatment, potable water was charged to the scrubber system, and then sampled and analyzed for volatile and semivolatile organic compounds, pesticides, dioxins/furans, and metals. The scrubber water was agaln sampled and analyzed for these parameters during treatment.

Samples of the stack gas were collected during treatment. The samples were analyzed for volatiles. semivolatiles, pesticides, dioxins/furans metals, hydrogen chloride, and particulates. The stack gas was also monitored for oxygen, carbon monoxide, and total hydrocarbons using continuous emission monitors.

System parameters including, but not limited to, voltage and amperage applied to the molten soil, hood vacuum, and off-gas treatment train operational attributes, were monitored durlng treatment. Measurements were taken every minute and recorded by computer. Additional parameters such as hood skln and plenum temperatures, scrubber pH and volume, and differential pressures across the scrubber system and filters were manually recorded regularly.

Three primary post-treatment vitrified soil samples were collected from the surface of Cell 8. Analysis of the surface samples was intended to provlde immediate information regarding the condition of the soil until samples more representatlve of the center of the treatment area can be safely obtalned. Additional sampling is scheduled to be performed after the molten mass has sufficiently cooled (in approximately one yr). The surface samples collected immediately after treatment were analyzed for pestlcldes, dioxins/furans, and metals. The TCLP was also performed on these samples to determine the leachability of the treated soil. Post-treatment samples were collected from the scrubber water and analyzed for volatile% semivolatlles, pesticides, dioxins/furans, and metals.

Table 2 summarizes the range of selected analytical results from samples collected during the Demonstration. Because of the limited number of samples collected, ranges are presented rather than average values. The data presented in this table are limited to analytes that were of concern during the Demonstration and important in evaluating test objectives. Concentrations below the respective reporting detection limits are indicated by a 'less than' symbol (i.e., <).

Evaluation of the data suggests the following results and conclusions:

- The technology successfully treated the soil, completing the test cell melt in ten days with only minor **operational problems.** During this time, approximately 330 yd^3 (approximately 600 tons) of contaminated soil was vitrified, according to Geosafe melt summaries. Approximately 613 MWh of energy was applied to the total soil volume (estimated to be 475 yd^3) durlng vitrification of Cell 8; energy applied to the actual contaminated soil volume could not be independently measured because clean fill and surrounding uncontaminated soil are vitrified as part of each melt. System operation was occasionally interrupted briefly for routine maintenance such as electrode system addition and adjustment.
- The treated (vitrified) soil met the EPA Region V cleanup criteria for pesticides and mercury. Target pesticides were reduced to levels below their analytical reporting detection limits (<80 µg/kg for chlordane, <16 µg/kg for 4,4'-DDT and dieldrin) in the treated soil. Mercury, analyzed by standard SW-846 Method 7471 procedures, was reduced to less than 40 µg/kg in the treated soil. Although the **concentration of** pesticides and mercury were below **the cleanup** criteria in some samples, significant contaminant reductions were achieved. Chlordane was not detected In any of the

Table 2. Selected Data Summary Results

Pesticides	Chlordane	4,4' DDT	Dieldrin
Pre-Treatment Soil (µg/kg)	<80	**2,400 - 23,100**	**1,210 - 8,330**
Post-Treatment Soil (µg/kg)	<80	**<16**	**<16**
Pre-Treatment TCLP (µg/L)	<0.5	0.120 - 0.171	6.5 - 10.2
Post-Treatment TCLP (µg/L)	<0.5	CO.1	<0. 1
Stack Emissions (µg/m³)	<1.38	<0.28	<0.28
Stack Emissions (lb/hr)	<1. 1 x10^{-5}	<2.2 x 10^{-6}	<2.2 x 10^{-6}

Metals	Arsenic	Chromium	Lead	Mercury
Pre-Treatment Soil (µg/kg)	8,380 –10,100	37,400 –47,600	<50, 000	2,220 - 4,760
Post-Treatment Soil (µg/kg)*	717 –5,490	12,500 –14,600	<5,000 - 21,000	<40
Pre-Treatment TCLP (µg/L)	NA	NA	NA	<0.2
Post-Treatment TCLP (µg/L)	<4 - 30.5	<10 - 17.1	<50 - 4,290	<0.2 - 0.23
Stack Emissions (µg/m³)	<O.269	2.081 - 3.718	<3.891	12.9 - 17.7
Stack Emissions (lb/hr)	<12.93x 10^{-6}	1.48 x 10^{-5} 2.67 X 10^{-5}	<2.82 x10^{-5}	9.89 X 10^{-5}- 1.25 X 10^{-4}

< *Indicates that analyte was not deteced at or above the reporting detection limit (value presented).*
* *Values presented were obtained using standard SW-846 digestion and analytical methods. These soil methods are EPA-approved, however, other non-approved methods may provide more accurate metal determinations for vitrified materials.*
NA *Indicates that the sample was not analyzed for this parameter.*

SITE Demonstration samples, but were detected in samples collected by EPA Reglon V.

- The solid vitrified material collected was subjected to TCLP for pesticidesand mercury. No target pesticides were detected in the leachate: the average leachable mercury wasapproximately 0.2μg/L, well below the regulatory limit of 200 μg/L (40 CFR Part 261.24).

- Stack gas samples were collected during the Demonstration Test to characterlze process emissions. There were no target pestlcldes detected In the stack gas samples. Durlng the Demonstration Test, mercury emlssions averaged 16 μg/m³ (1.1 x10⁻⁴ lb/hr). The emlssions were below the regulatory requirement of 88 μg/m³ (5.93 x 1 0⁻⁴ lb/hr). Other metal emissions in the stack gas (specifically arsenic, chromium, and lead) were monitored and found to meet regulatory standards during testing. Stack gas dispersion modeling by Reglon V Indicated that metal emlssionsdurlng treatment were not a human health risk.

- Emissions of total hydrocarbons and carbon monoxide were regulated at 100 ppmV (as propane) and 150 ppmV, respectively. Throughout the Demonstration Test, vapor emissions of these gases (measured downstream from the thermal oxidizer) were each consistently below 10 ppmV-well below the regulatory guidelines.

- Scrubber water generated during the Demonstration Test contained volatile organlcs, partially oxidized semivolatile organics (phenolics), mercury, and other metals. The scrubber water underwent secondary treatment off-site before ultimate disposal and data suggest that secondary treatment of this waste stream is likely In most cases.

- Pre-treatment soil drydensityaveraged 1.48tons/yd³, while post-treatment soil dry density averaged 2.10 tons/yd³. On a dry basis, a volume reduction of ap proximately 30 % was observed for the test soil.

Key findings from the demonstration, including complete analytical results and the economic analysis, will be published in an Innovative Technology Evaluation Report. Thls report will be used to evaluate the Geosafe ISV Technology as an altermative for cleaning up similar sites across the country. Information will also be presented in a SITE Demonstration Bulletin and a videotape.

Economic Analysis

Estimates on capital and operating costs have been determined for a treatment volume of approximately 3,200 yd³ (5,700 tons). This is slightly higher than the total treatment volume at the Parsons site, but it is based on the treatment configuration used at this site (nine treatment cells measuring 27 ft by 27 ft by 15 ft deep with 2 ft of clean fill on top of the contaminated soil). This information was extrapolated to determlne a treatment cost for remediating approximately 970 yd³ (nine treatment cells measuring 27 ft by 27 ft by 5 ft deep with 1 ft of clean fill) and approximately 4,400 yd³ (nine treatment cells measuring 27 ft by 27 ft by 20 ft deep with 2 ft of clean fill). The cost for the treatment of approximately 3200 yd³ (5,700 tons) of soil is based on the SITE demonstration at the Parsons site and is estimated to be approximately $780/yd³ ($430/ton). For lesser volumes of soil (970 yd³, as described above), the cost becomes approximately $1,500/yd³ ($858/ton). For larger volumes of soil (4,400 yd³, as described above), the cost becomes approximately $670/yd³ ($370/ton) The primary determinants of cost are the local price of electricity, the depth of processing, and the soil moisture content. Treatment volume (and therefore treatment time) is the key variable between the costs of these three cases. The cost of time-dependent factors including equipment rental, labor, consumables and supplies, and utilities varles directly with treatment time.

The prlmary cost categories include utilities, labor, and startup and fixed costs, each contributing roughly 20% to the total cost (utilities slightly higher). The contributlon of utilities increases markedly with increased treatment volume. Equipment costs and facllities modifications and maintenance costs are each responsible for roughly 10% of the total treatment cost. Treatment is most econoMlcal when treating large sites to maximum depths, particularly since time between melts is minimal compared to actual treatment time.

The cost for treatment using the Geosafe ISV technology is based on, but not limited to, the following assumptions:

- The contaminated soil is staged into treatment cells by an independent contractor prior to Geosafe's arrival on-site. Cell preparation and construction are site-specific and may be different for each case, however, it Is assumed that each site is prepared in a manner simllar to the Parsons site.

- The depth of treatment is assumed to exceed the depth of contamination by at least one ft to ensure that the melt incorporates the floor of the cell and beyond.

- Treatment takes place 24 hr/day, 7 days/wk, 52 wk/yr. An on-line efficiency factor of 80% has been incorporated to account for down-time due to scheduled and unscheduled maintenance and other unforeseen delays.

- Operations for a typical shift require one shift engineer and one operator. In addition,onesite manager and one project control specialist are present on-site during the day shift. Three shifts of workers are assumed to work elght hr/day, seven day/wk for three weeks. At the end of three weeks, one shift of workers is rotated out, and a new set replaces the former.

- The costs presented (in dollars/cubic yard) are calculated based on the number of cubic yards of contaminated soil treated. Because clean fill and surrounding uncontaminated soil are treated as part of each melt, the total number of cubic yards of soil treated is higher than the number of cubic yards of contaminated soil treated. Costs/cubic yard based on total soil treated would, therefore, be lower than the costs presented in thls estimate.

If Geosafe scales its process differently than assumed in this analysis (a likely scenario), then the cost of remediation/cubic yard of contaminated soil will change.

These cost estimates are representative of charges typically assessed to the client by the vendor and do not include profit. The costs presented in this economic analysis are based upon data gathered at the Parsons site. The developer claims these costs were unusually high, and expects the treatment costs for future sites to be less than the treatment costs for the Parsons site. A detailed explanation of these costs is included in the Innovative Technology Evaluation Report.

Technology Status

The technology was originally developed by Pacific Northwest Laboratory, operated by Battelle Memorial Institute, and has been undergoing testing and development since 1980. A majority of the development work was performed by the US. Department of Energy, however, significant work also has been done for various private and other government sponsors. The technology has been licensed exclusively to Geosafe Corporation for the purpose of commercial applications of hazardous and radioactive waste remediatlon. To date, the technology has been tested on a wide variety of hazardous chemical. radioactive, and mixed wastes. Treatability tests are typically conducted on an englneering scale (100 to 200 lb melts) to determlne potential applicability of the technology. Geosafe has also conducted full-scale in situ operatlonal acceptance tests at thelr facility in Rlchland, WA. The work performed at the Parsons site was the first commercial full-scale application of the ISV technology.

The Records of Decision for five U.S. Department of Defense and EPA-lead Superfund sites (including the Parsons site) have identified ISV technology as the preferred remedy for cleanup. ISV also has been identified as an alternative cleanup option at two additional sites. Currently, Geosafe is scheduled to perform full-scale remedlatlon activities for other customers at sites contaminated with PCBs, chlorinated organlcs, and toxic metals. Treatment at each of these sites involves some amount of debris or otherwise foreign materlals. In situ or staged in sltu configurations will be used for the planned remediatlons.

Higher levels of contamination at other sites are not expected to represent a significant challenge to the process. For these sites, it may be possible to obtain destruction and removal efficiencies (DRE) if contaminants are present at high enough levels. DRE calculations were not possible at the Parsons site due to the low levels of target organics.

Operational parameters that affect the overall process performance have a much larger influence on successful application of ISV than contamination levels. Factors such as high soil moisture, extreme depths (deep or shallow), the presence of sealed drums, and soil composition are the primary factors that influence remedlal design and operatlon. With proper management, it is anticipated that the process may successfully be applied at other sites with higher levels of contamination.

SITE Program Description

In 1980, the U.S. Congress passed the Comprehensive Envlronmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund. CERCLA was amended by the Superfund Amendments and Reauthorlzatlon Act (SARA) In 1986. The SITE Program is a formal program established in response to SARA. The prlmary purpose of the SITE Program is to maximize the use of alternatives in cleaning up hazardous waste sites by encouraglng the development and demonstration of new, innovative treatment and monitoring technologies. It consists of four major elements: the Demonstration Program, the Emerging Technology Program, the Monitoring and Measurement Technologies Program, and the Technology Transfer Program. The Geosafe ISV Technology was demonstrated under the Demonstration Program. This Capsule was published as part of the Technology Transfer Program.

Disclaimer

While the technology conclusions presented in this report may not change, the data has not been reviewed by the Quality Assurance/Quality Control office.

Sources of Further Information

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